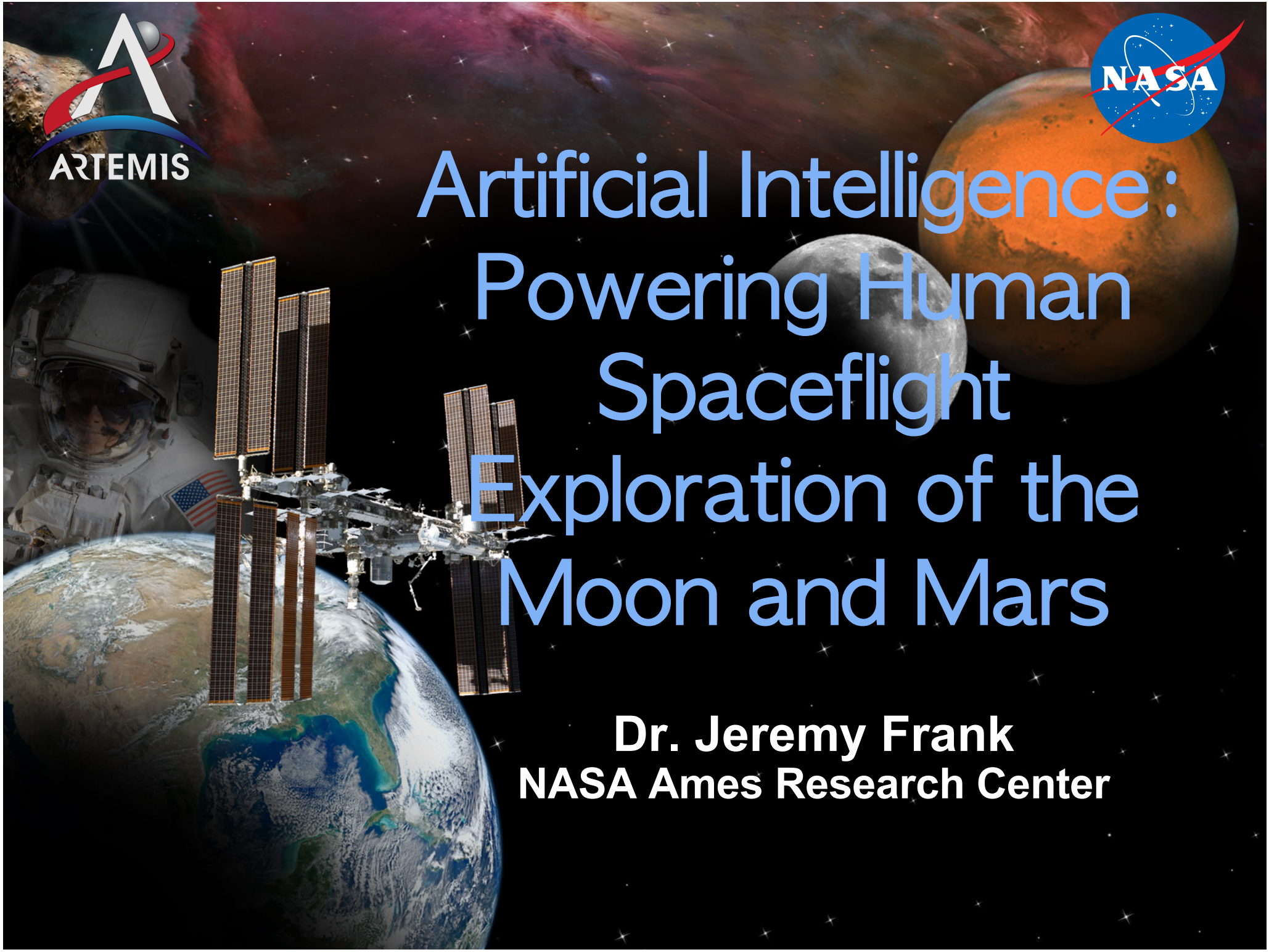

ARTEMIS
NASA
Artificial Intelligence: Powering Human Spaceflight Exploration of the Moon and Mars
Dr. Jeremy Frank
NASA Ames Research Center

What are we going to Learn Today?

Where are we going?

- The Moon and Mars

Mission Operations

- Communications Time Delay

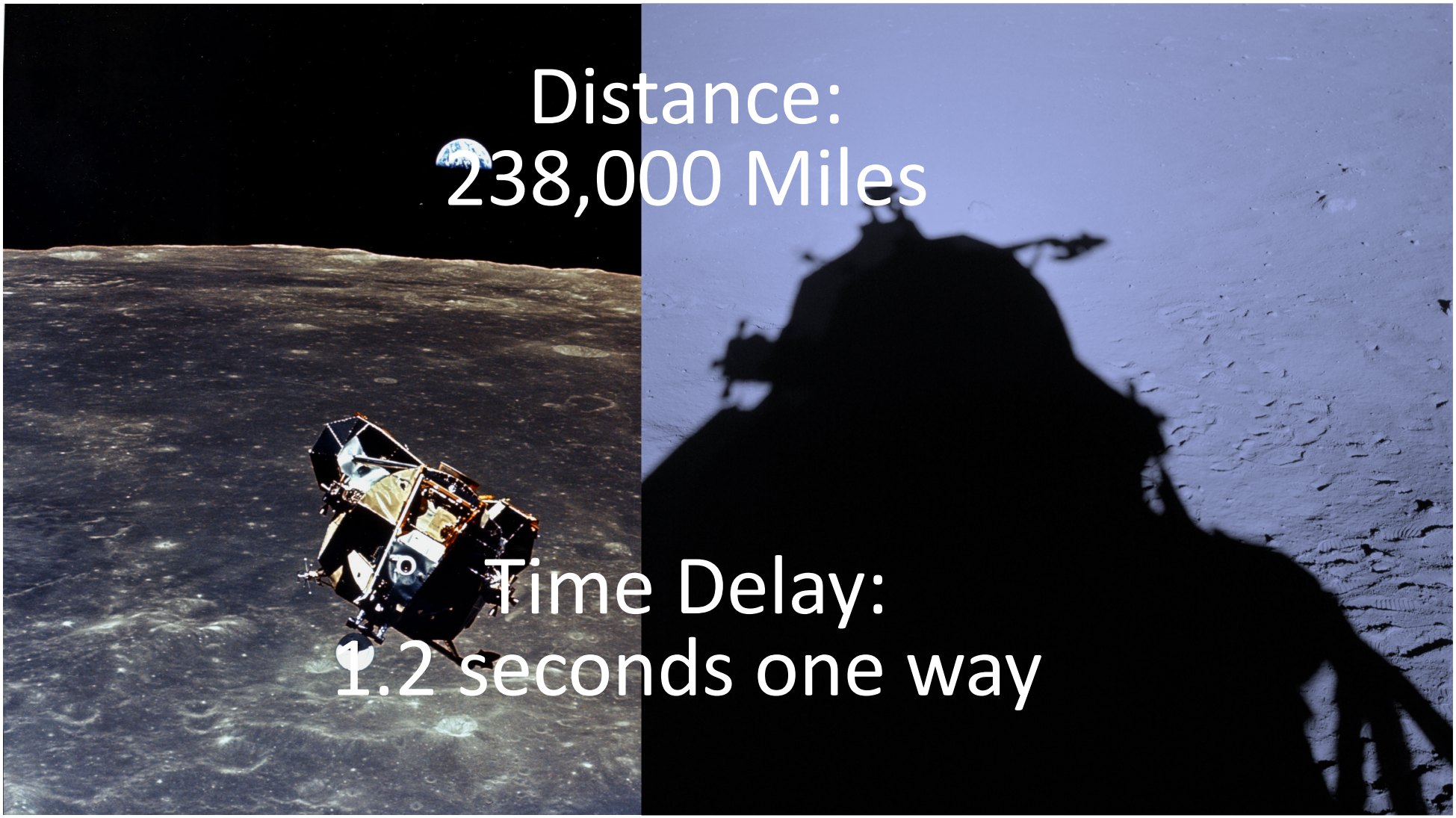
Artificial Intelligence Technology

- Planning
- Plan Execution
- Fault Management

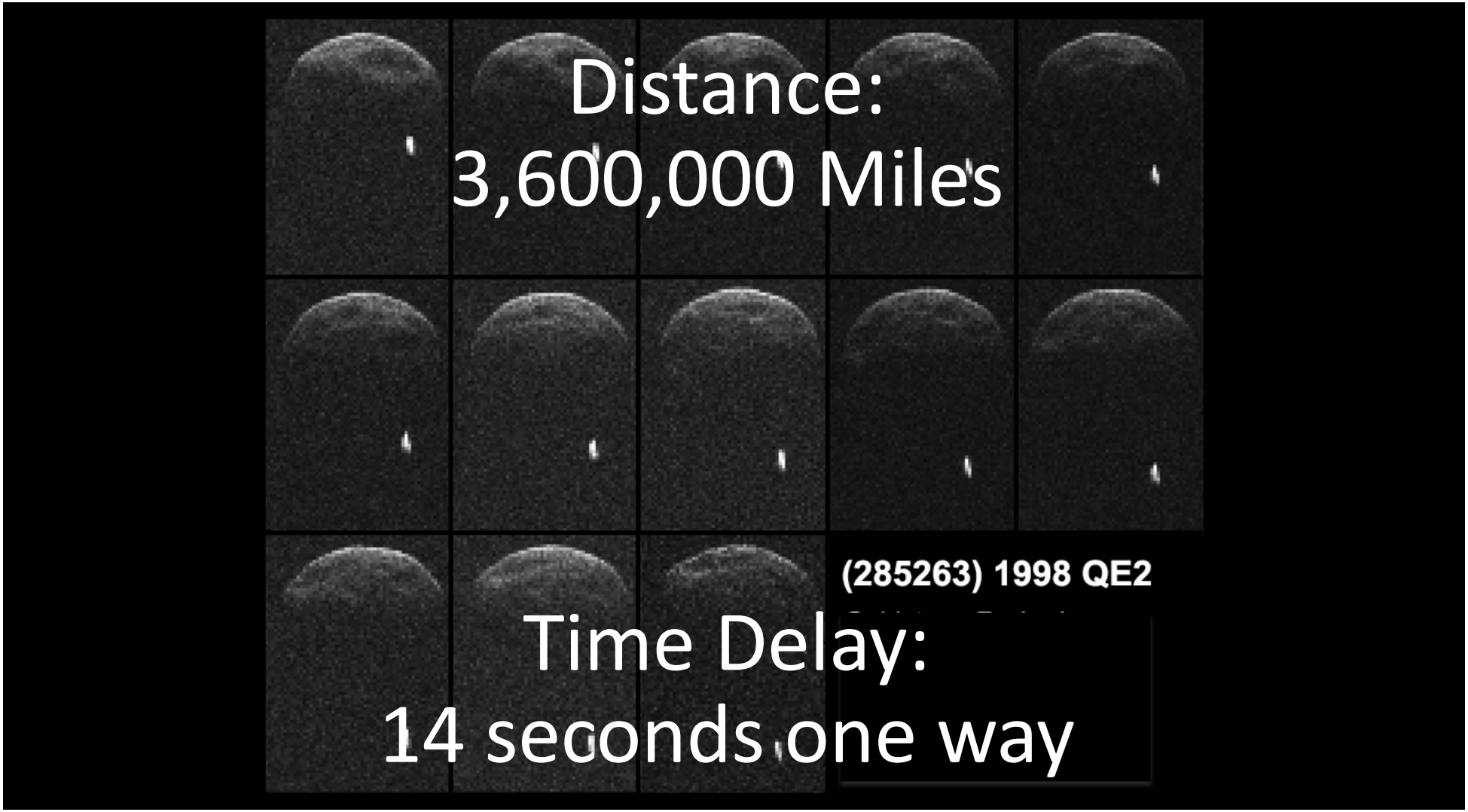
Making it Happen!

- Helping Astronauts
- Making Spacecraft Smart
- ...and More!

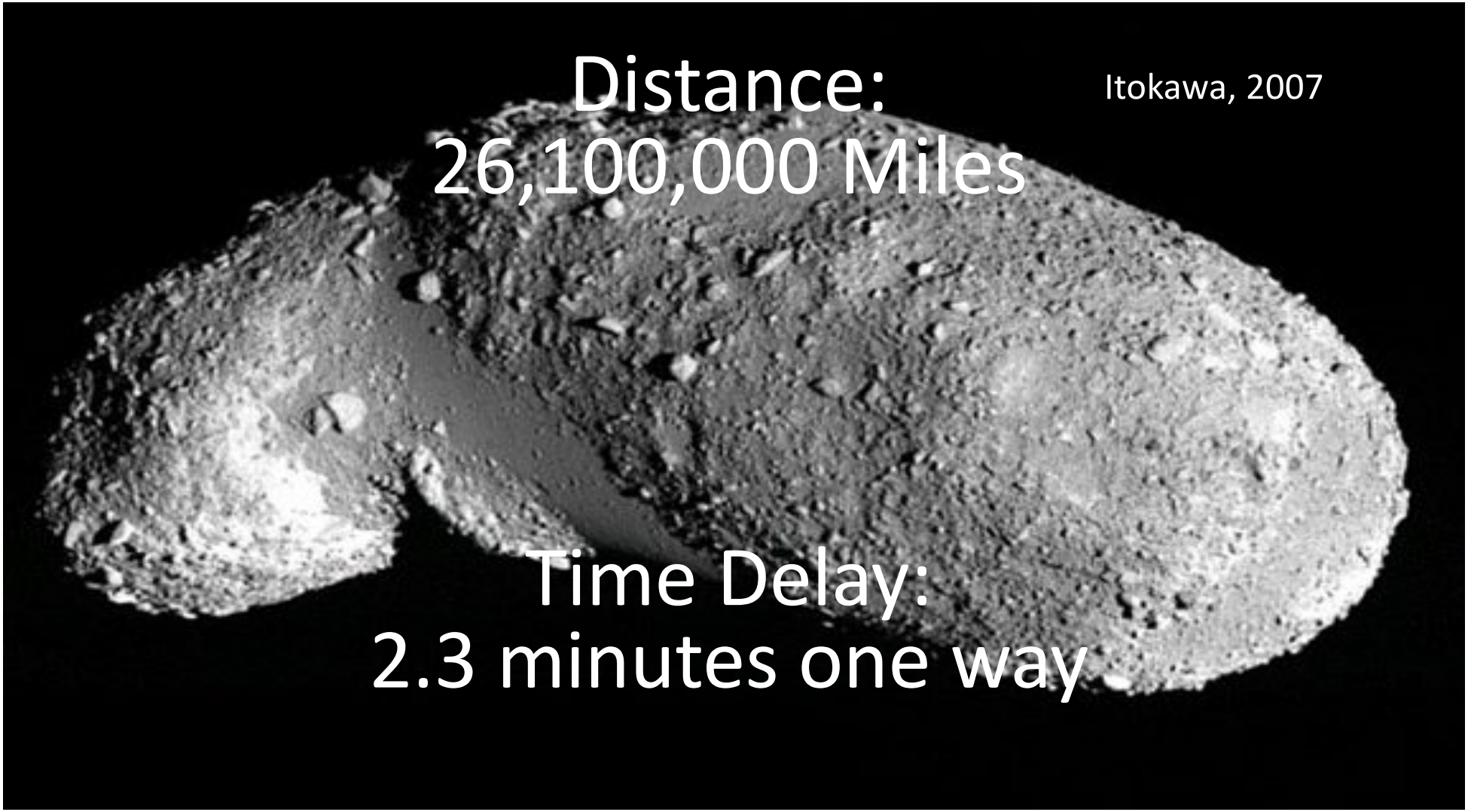
Destinations: The Moon



Destinations: Near Earth Asteroids



Near Earth Asteroids



Destinations: Mars

Destinations: Mars

NASA's Plan: Artemis

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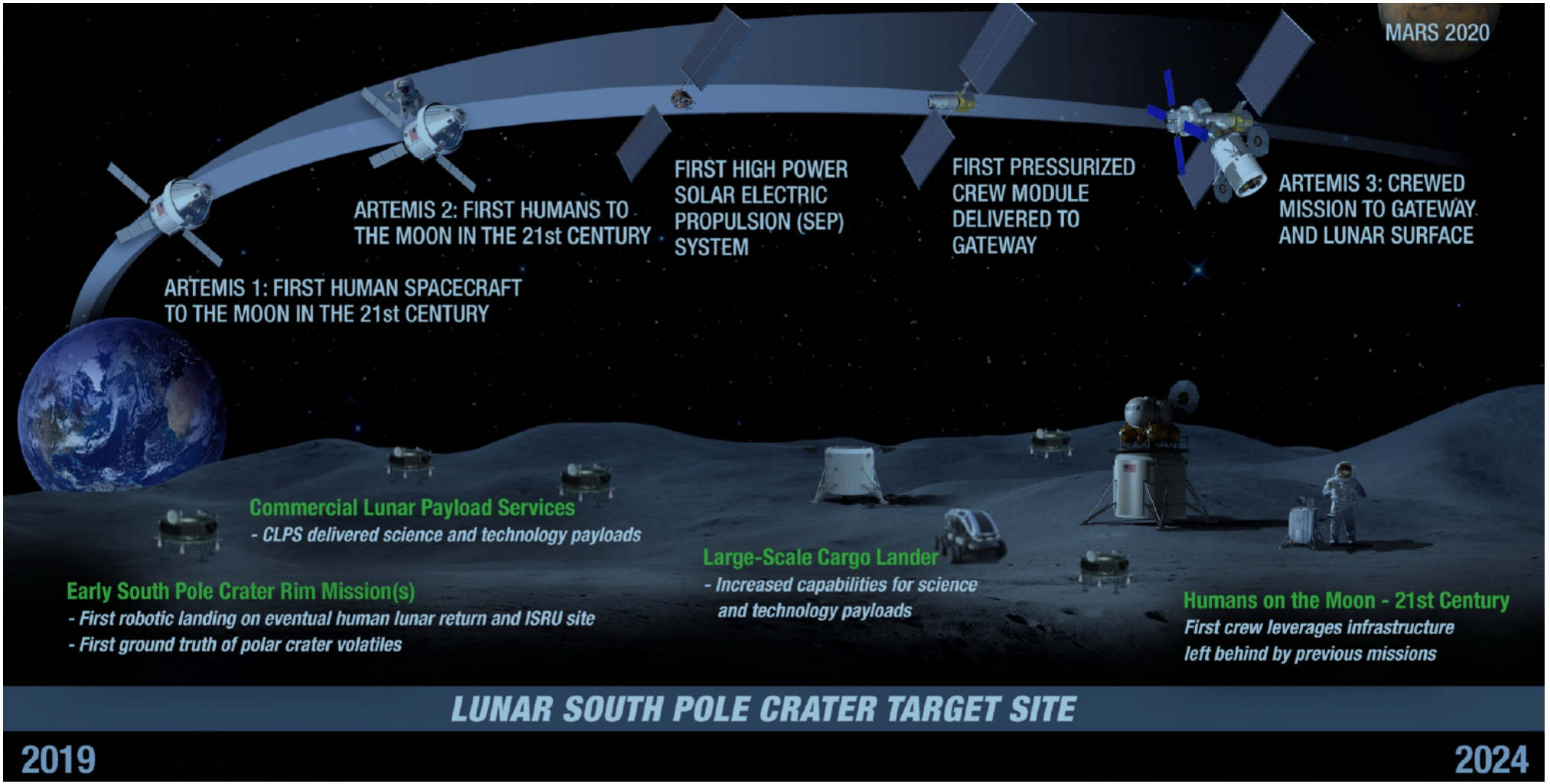


Mission Control and Time Delay

Communications

A Brief and Woefully Incomplete History:

- Stage Coach -1860 (weeks)
- Pony Express 1860-1861 (days)
- Telegraph 1861- (minutes)
- Trans-oceanic telegraph 1866
- Telephone 1876 (switchboards 1894)
- Fax 1964
- Electronic Mail (ARPANet) 1971
- Texting (SMS) 1994

Communications

Days

Minutes

Voice, Instant

Print, Instant

Instant

Communications

Days

Minutes

Voice, Instant

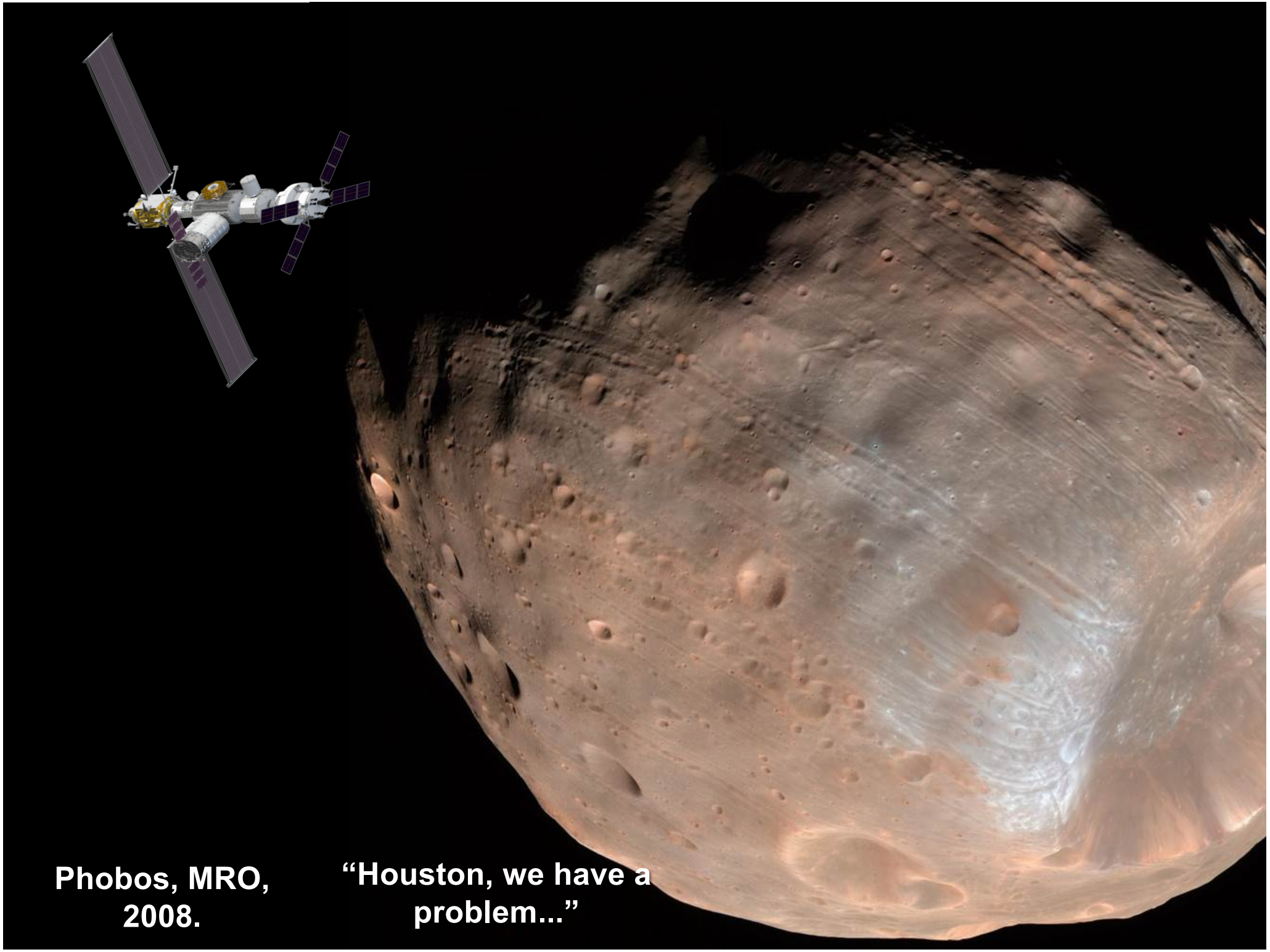
Print, Instant

Instant

Mission Control Functions

Mission Control is:

- The Power Company
- The Plumber
- The A/C Repairman
- The Doctor
- The Phone Company
- Geek Squad
- …
- Effective Mission Operations requires COMMUNICATION!


Phobos, MRO, 2008.
“Houston, we have a problem...”

Audience Participation Game!

Hello, Artemis, this is Mission Control, how can I help you?

When was the last time you cleaned the toilet?

Have there been any interruptions in power?

Our toilet hasn't been working for the last day.

We last serviced it three weeks ago.

No, the power hasn't gone out.

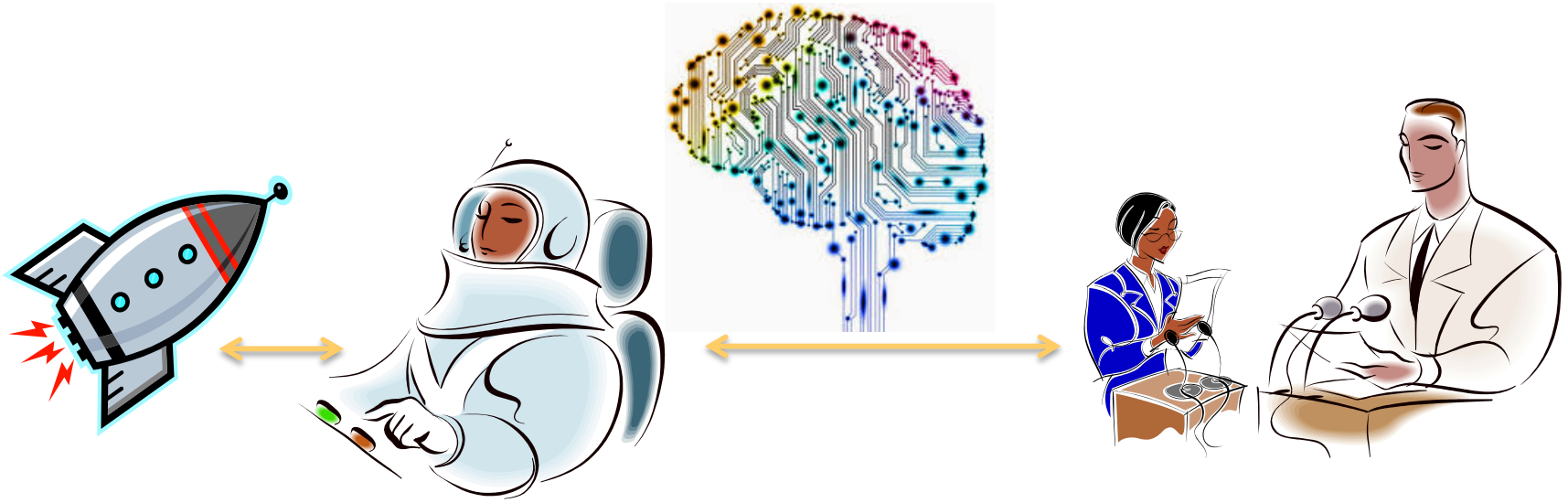

Artificial
Intelligence

Handling Communication Delay

How do we make the spacecraft smart?

How do we make the astronauts smarter?

Solution: Use Artificial Intelligence!



Artificial Intelligence

What is AI?

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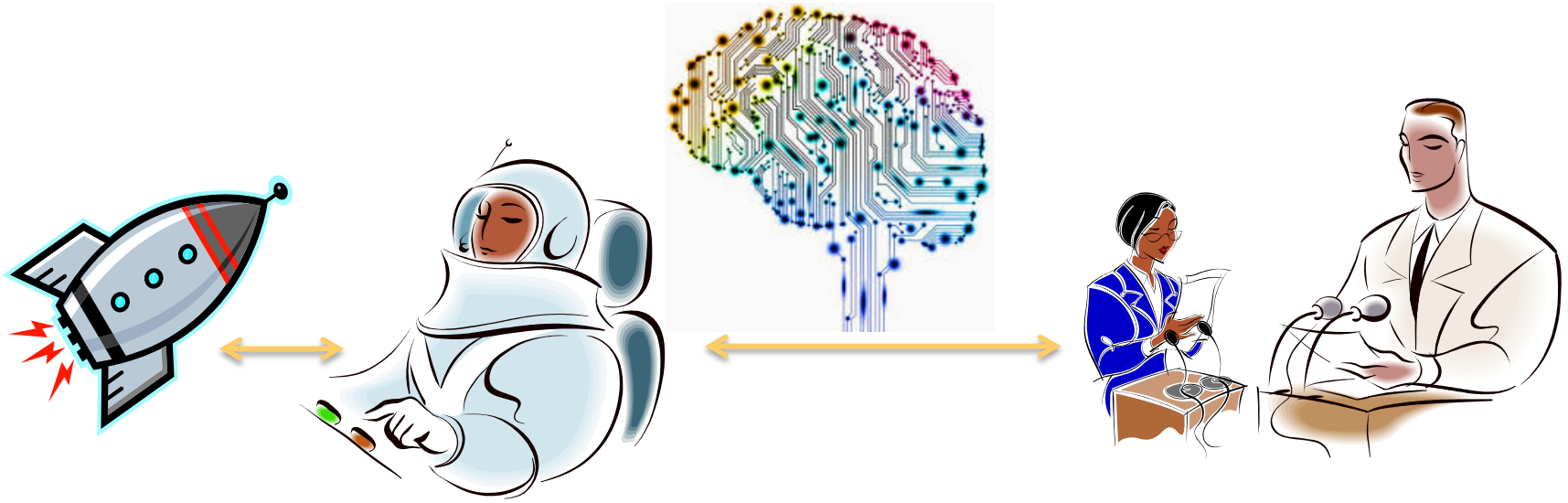
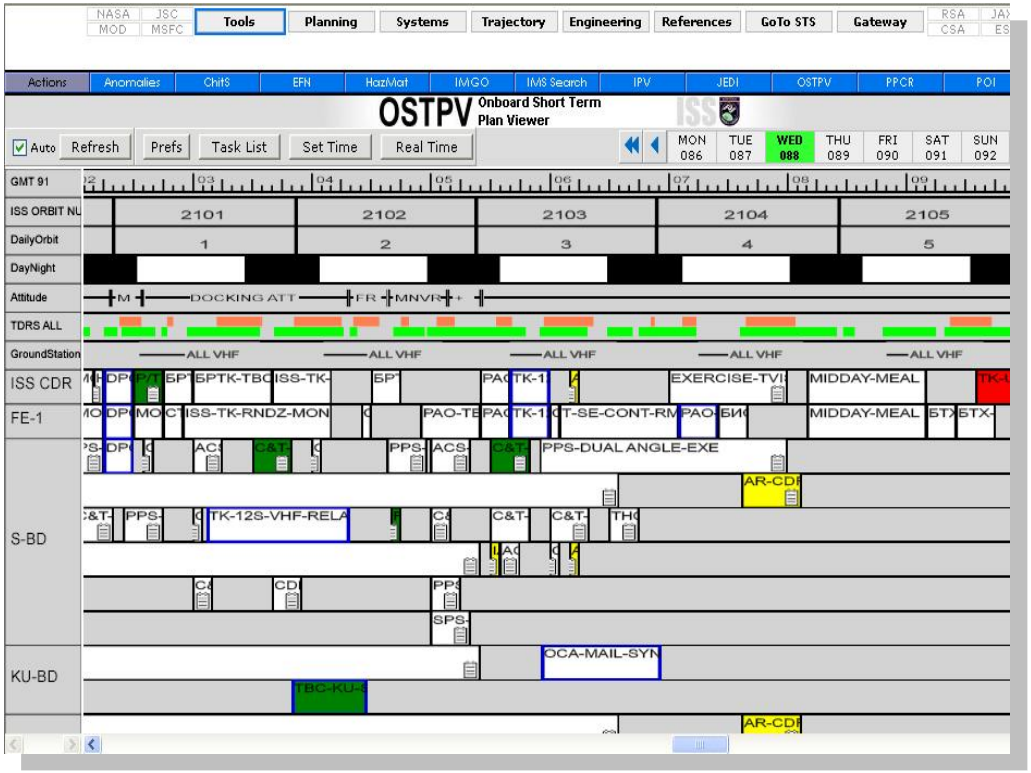


Planning and Scheduling

Purpose

- **Build a plan by choosing activities** to achieve goals.

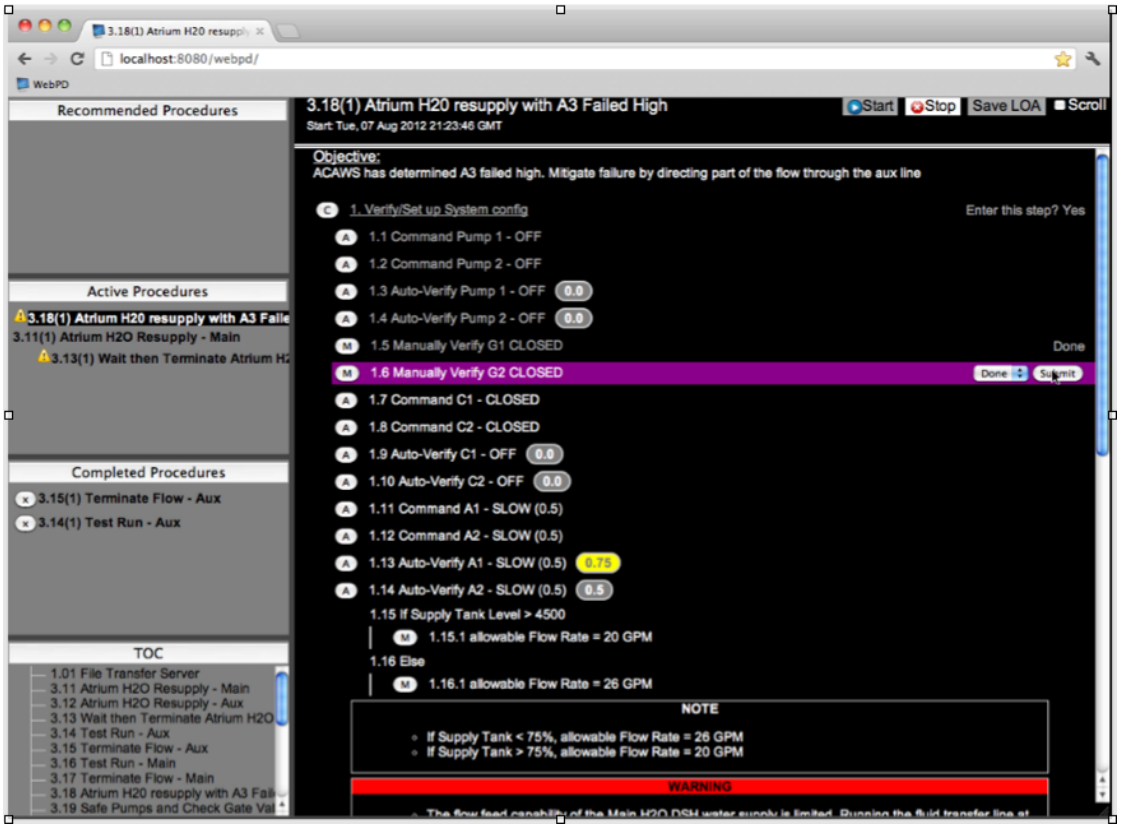


- **Applications:** Planning astronaut activities, science experiments, equipment maintenance.

Task Execution

Purpose

- **Carry out a plan** using an appropriate execution strategy.

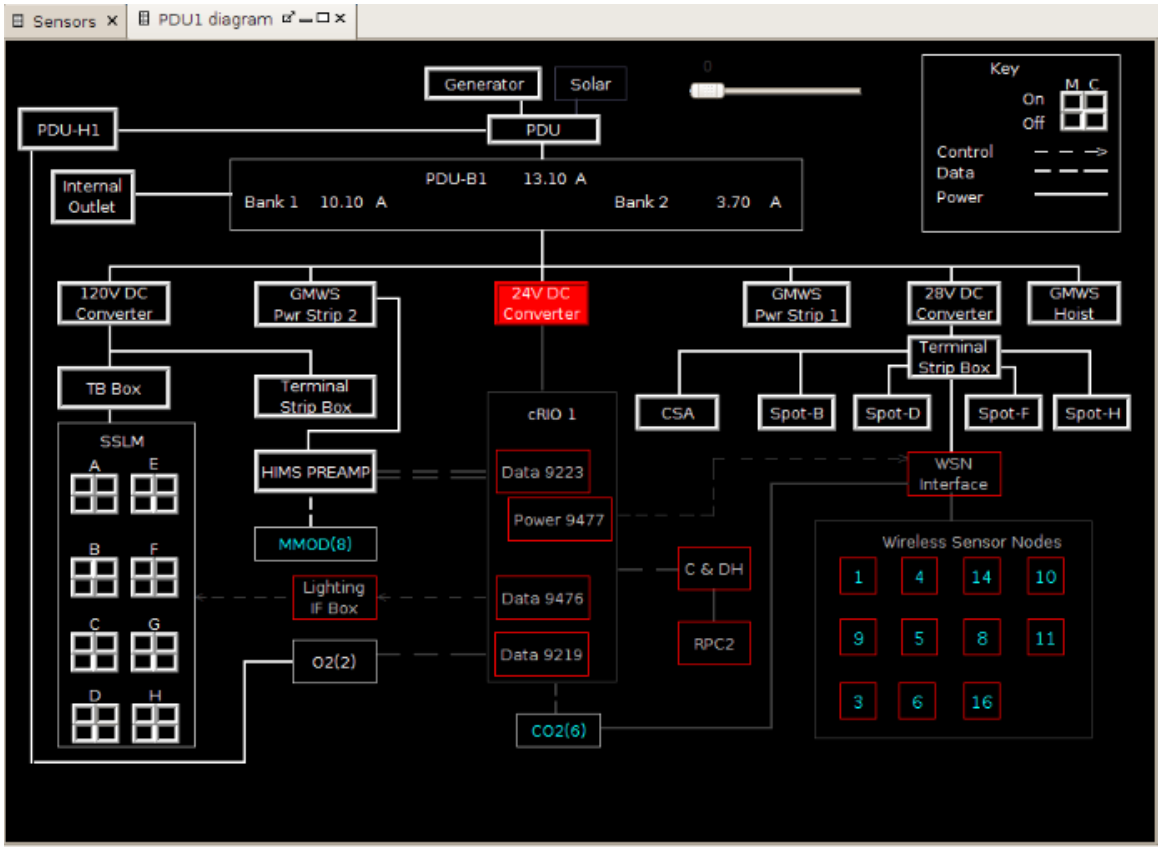


- **Applications:** Automating spacecraft systems, help astronauts perform tasks, automating robots

Fault Management

Purpose

- Monitor system to determine whether **faults** have occurred.
- Determine what faults have taken place.
- Assess remaining system **capability**.

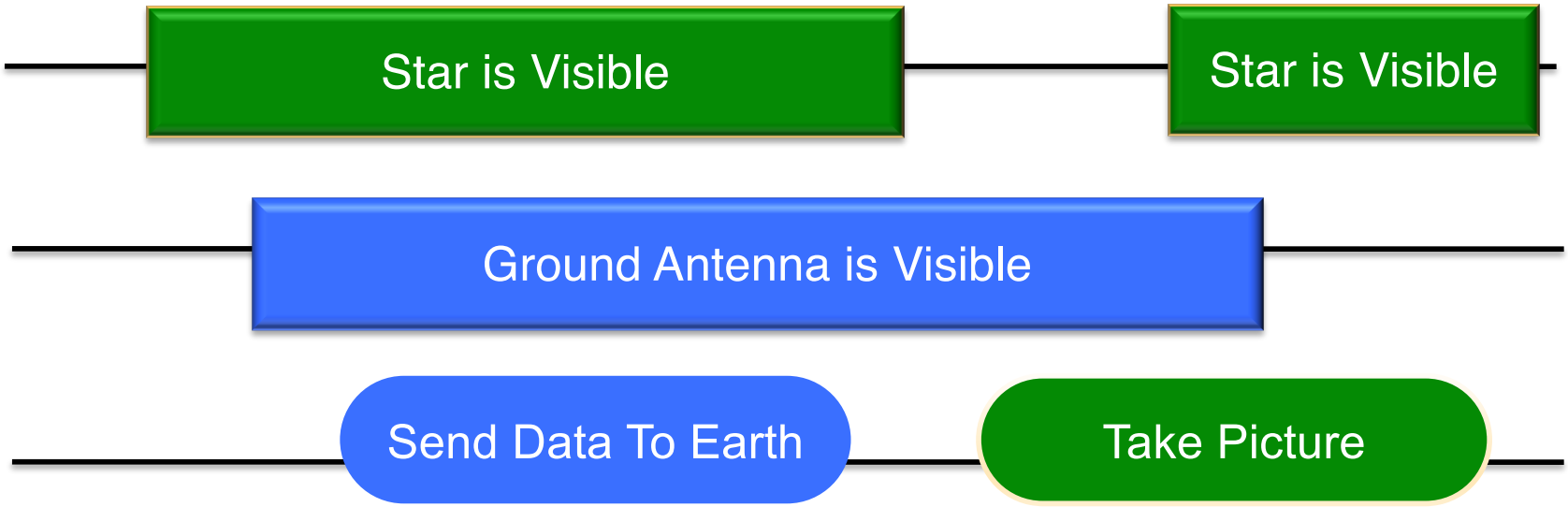


A Word About AI and Math

These AI capabilities use a form of mathematics called Automated Reasoning.

Example: How do we schedule activities ‘Take Picture’ and ‘Send Data to Earth’?

Each activity must fit in a ‘window’ of the ‘right color’, and they may not overlap.



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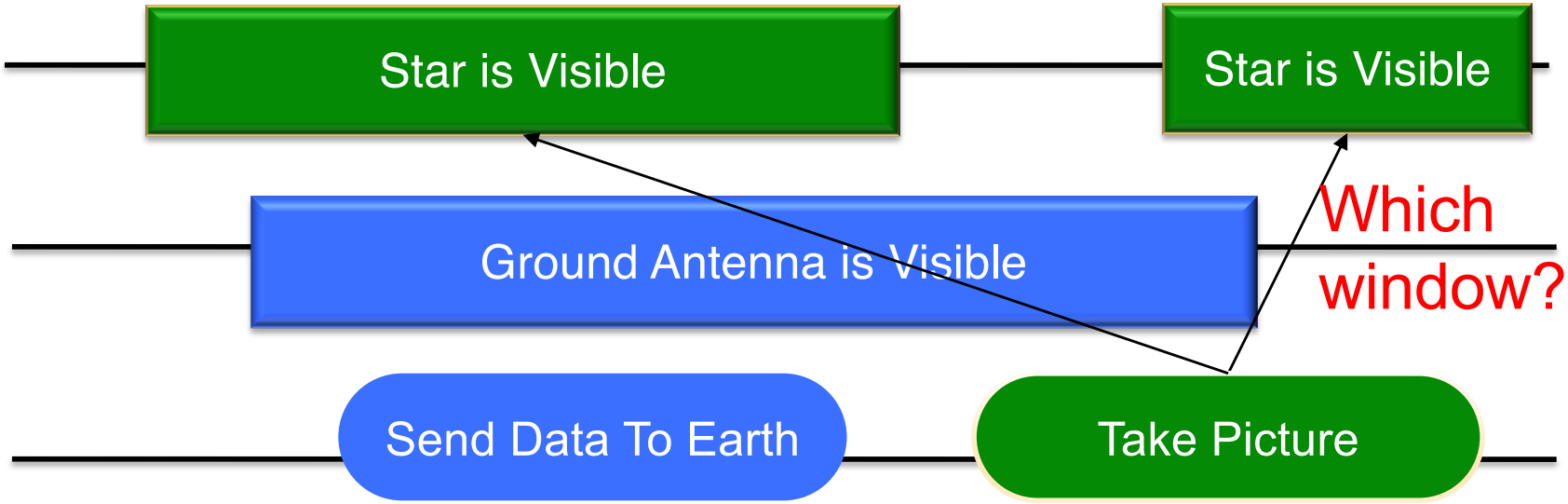

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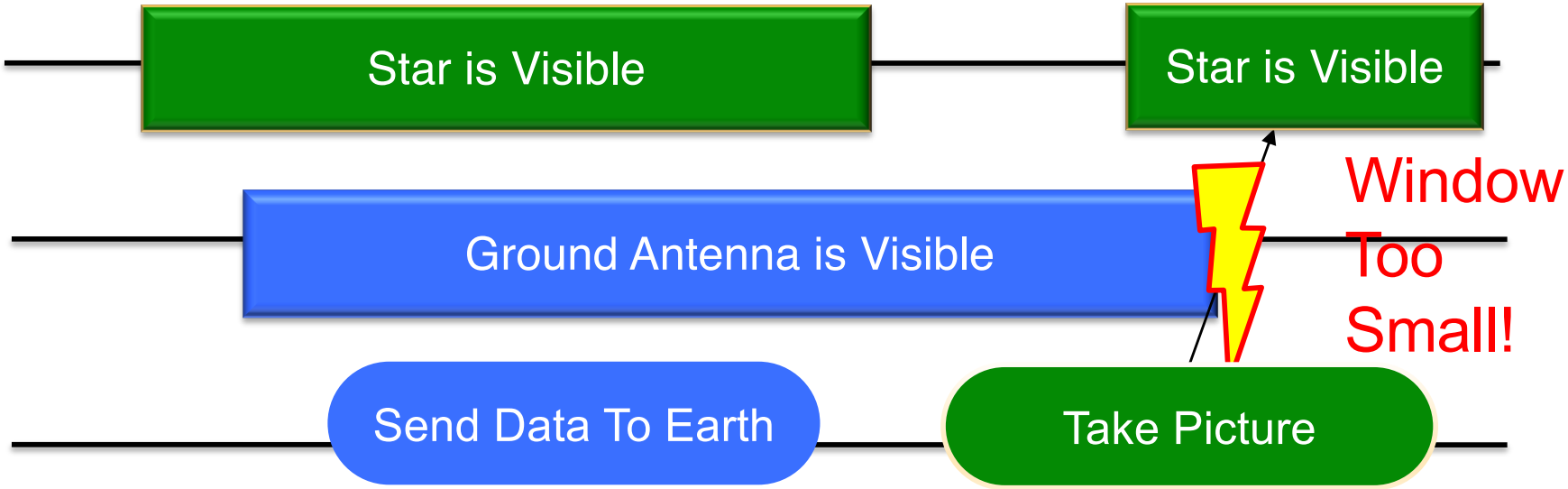

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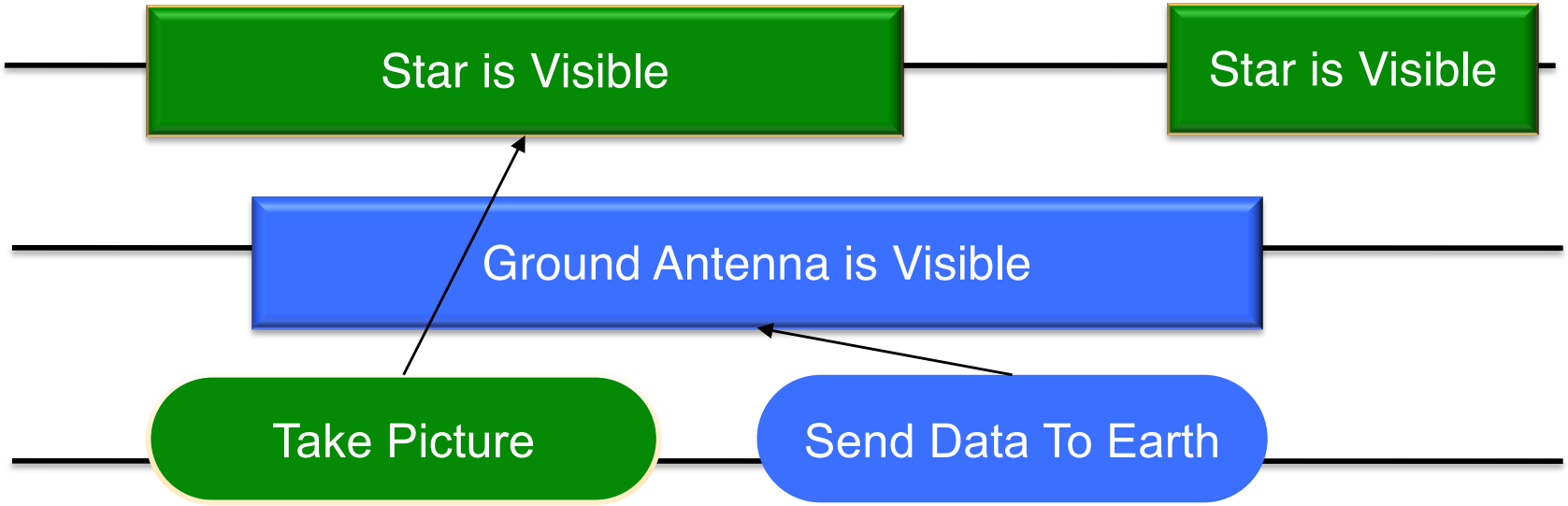

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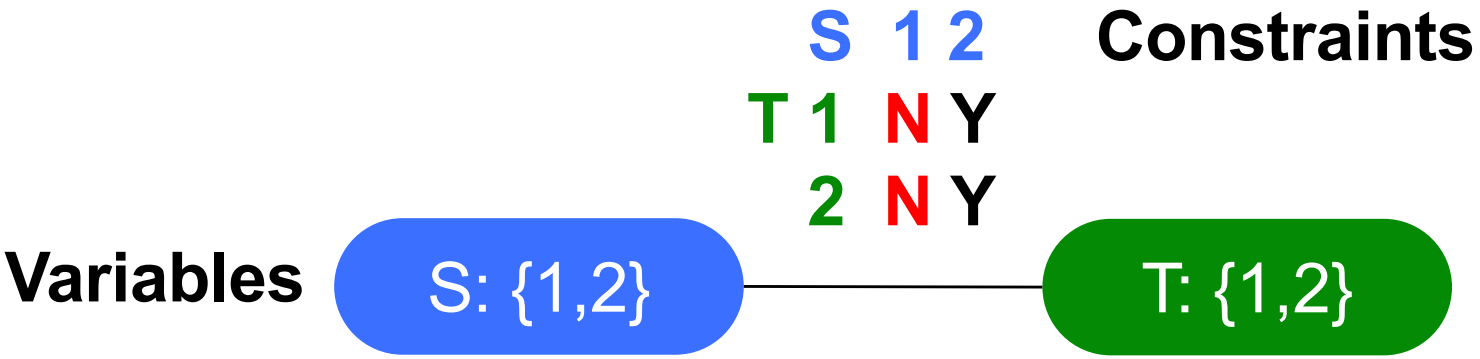

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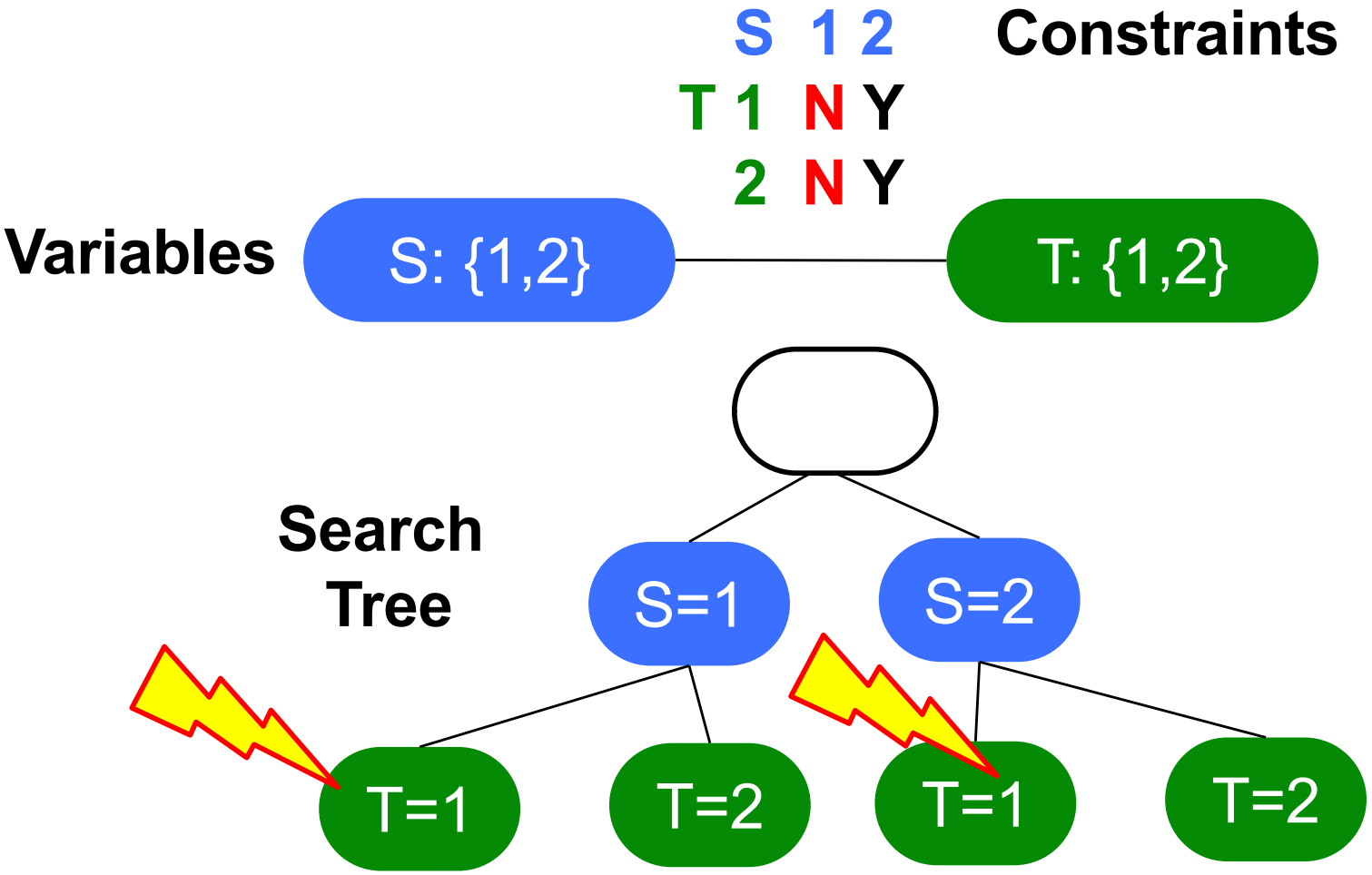

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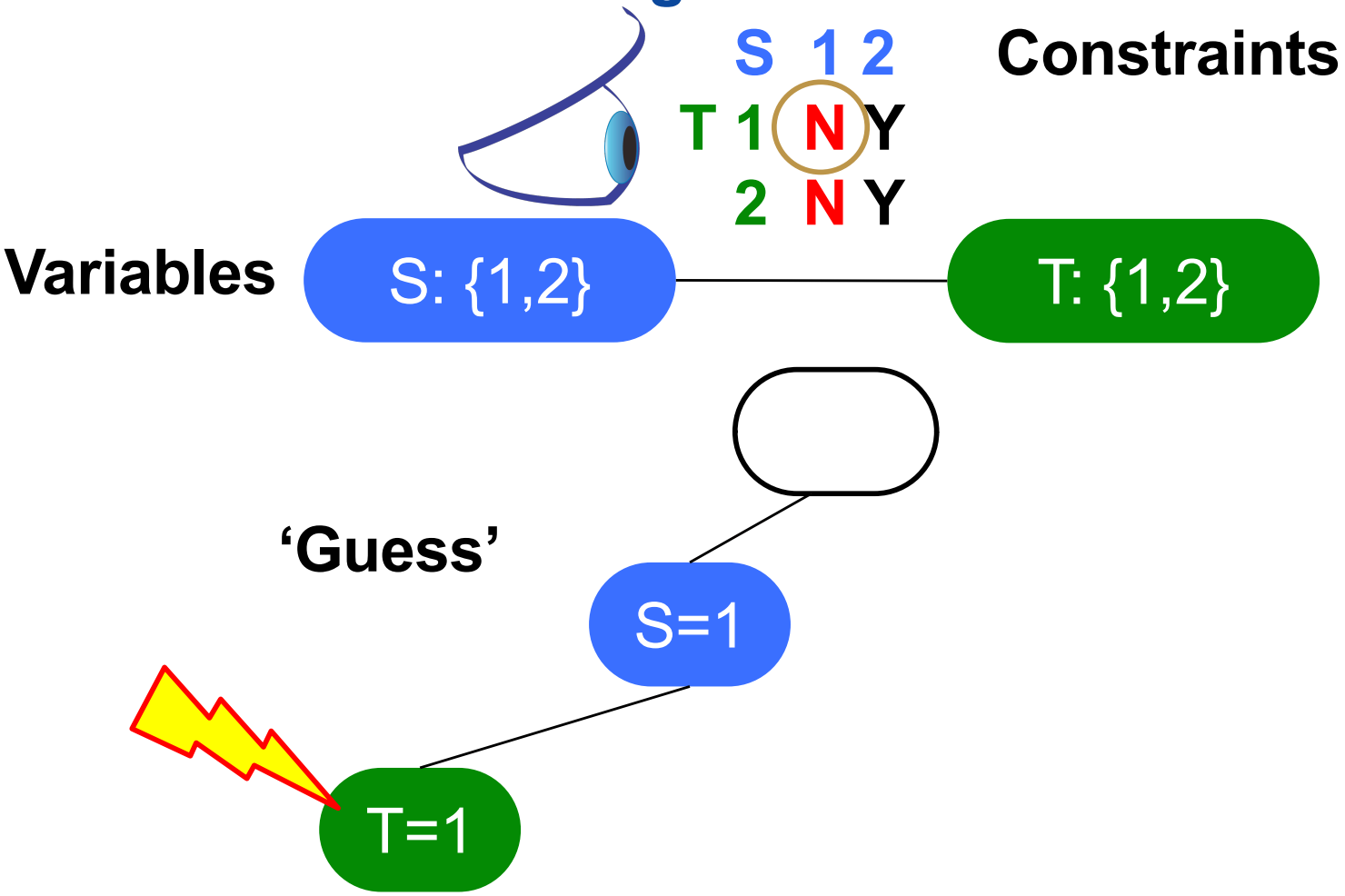

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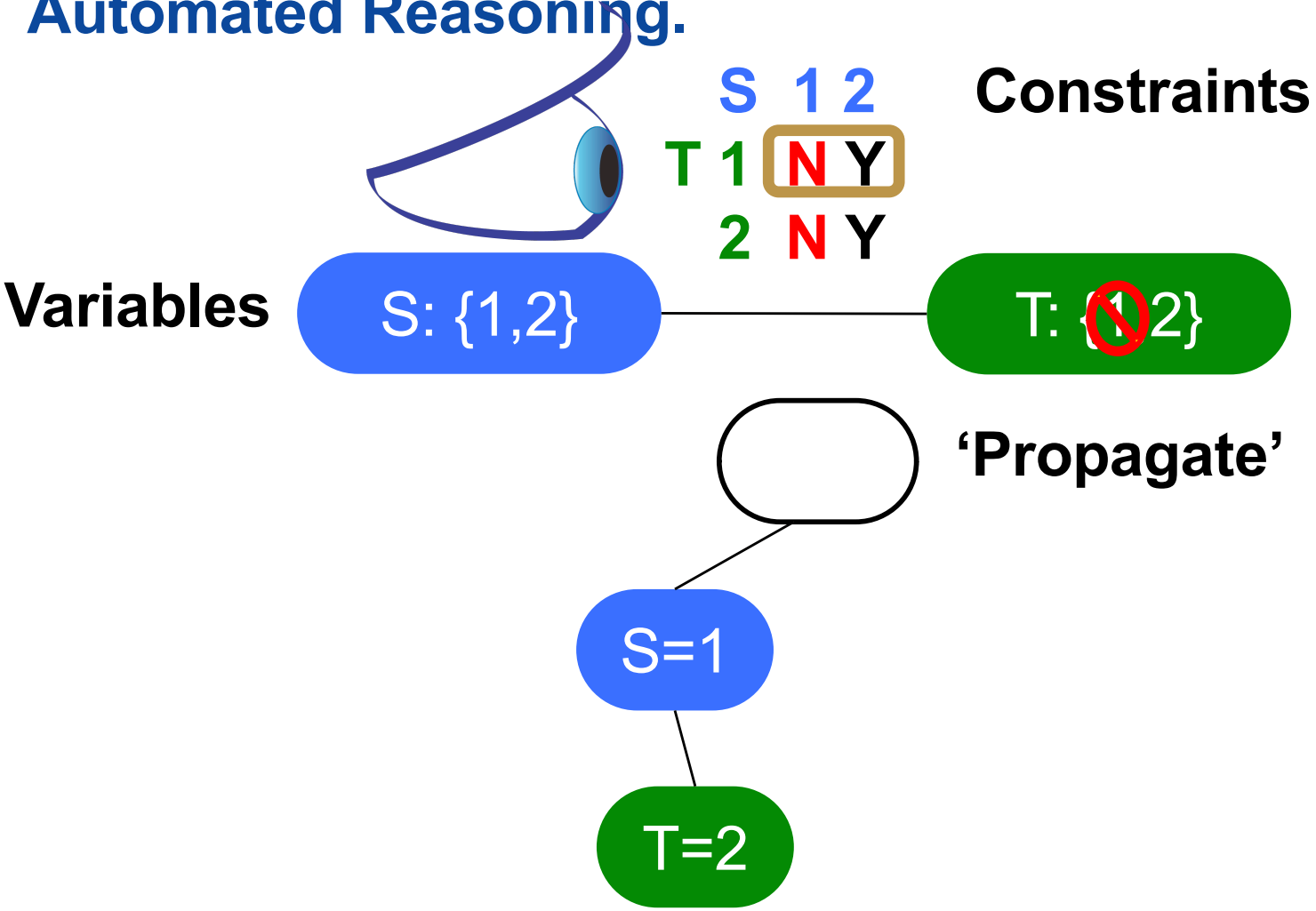

Putting All the Pieces Together

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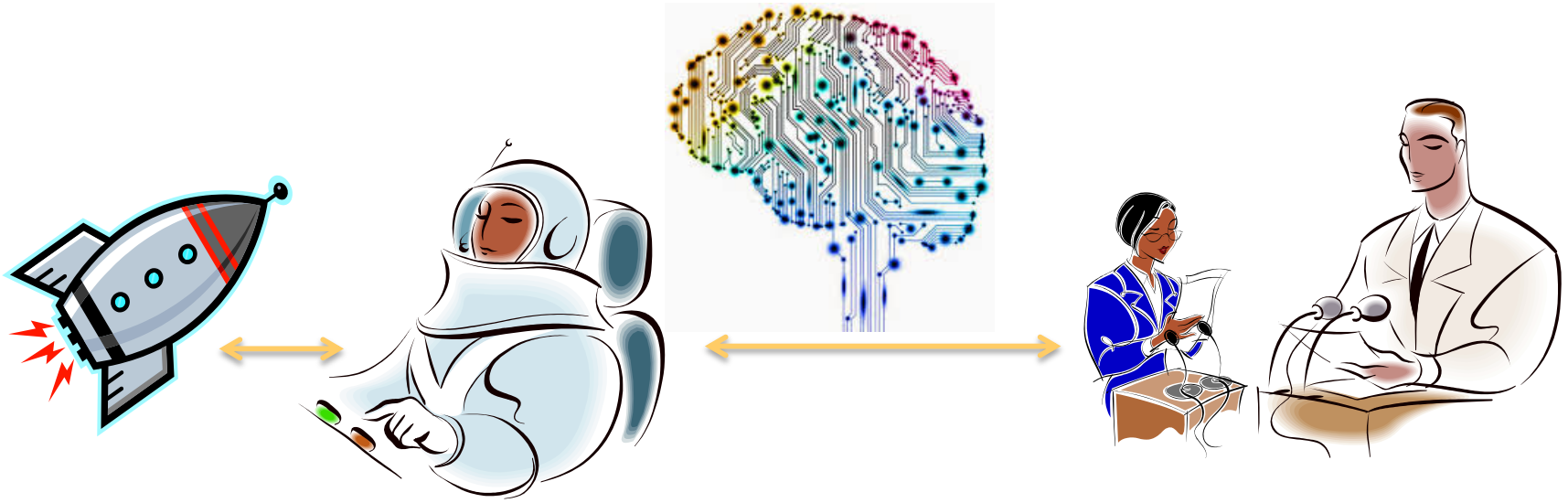

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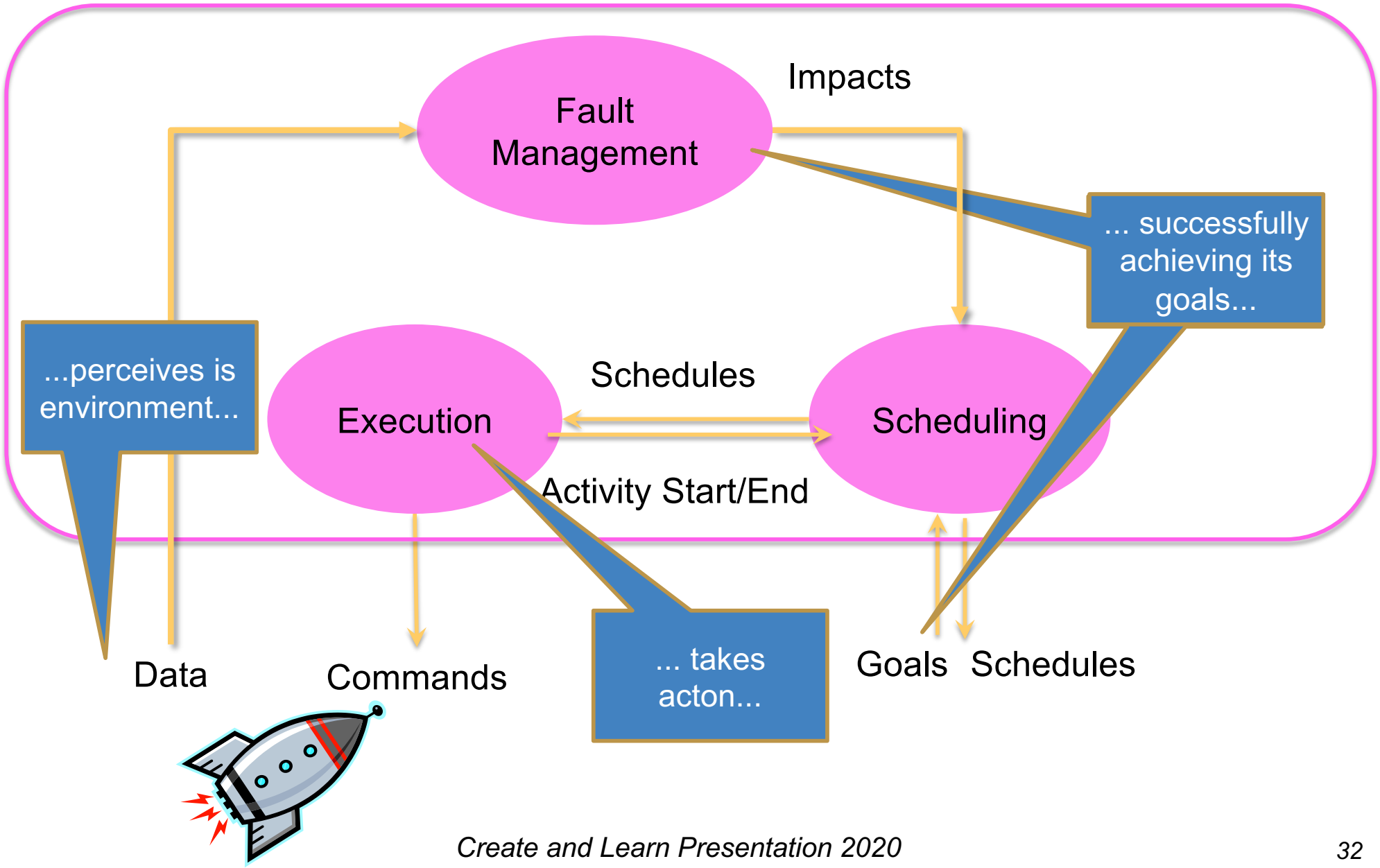


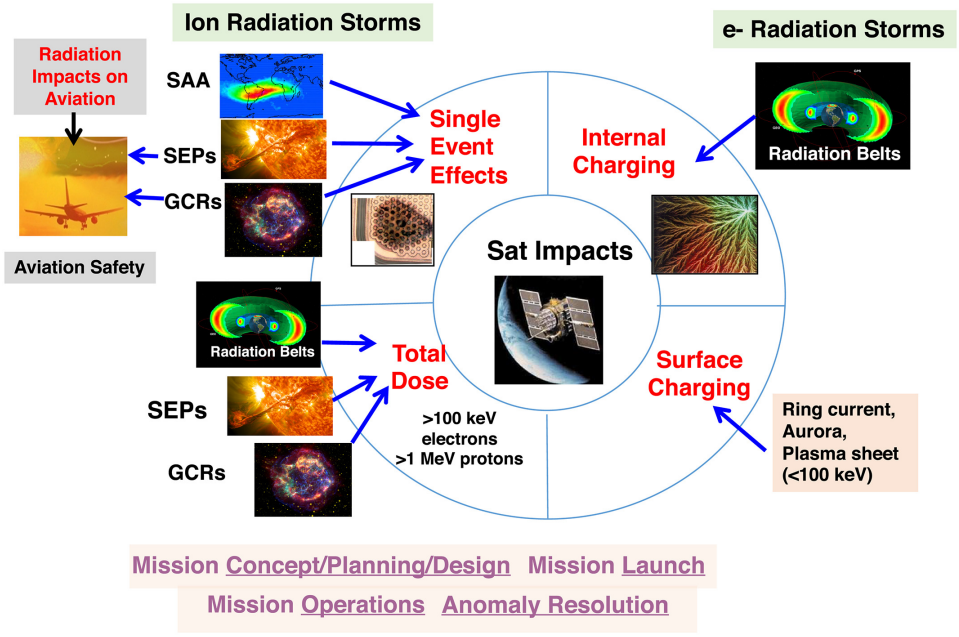
A Word on Software and Spacecraft

AI software is implemented in many different languages.

C, C++, Java, Python...etc...

For spaceflight, software must run on special computers.

AI software also requires information from sensors, which imposes design constrains on spacecraft...



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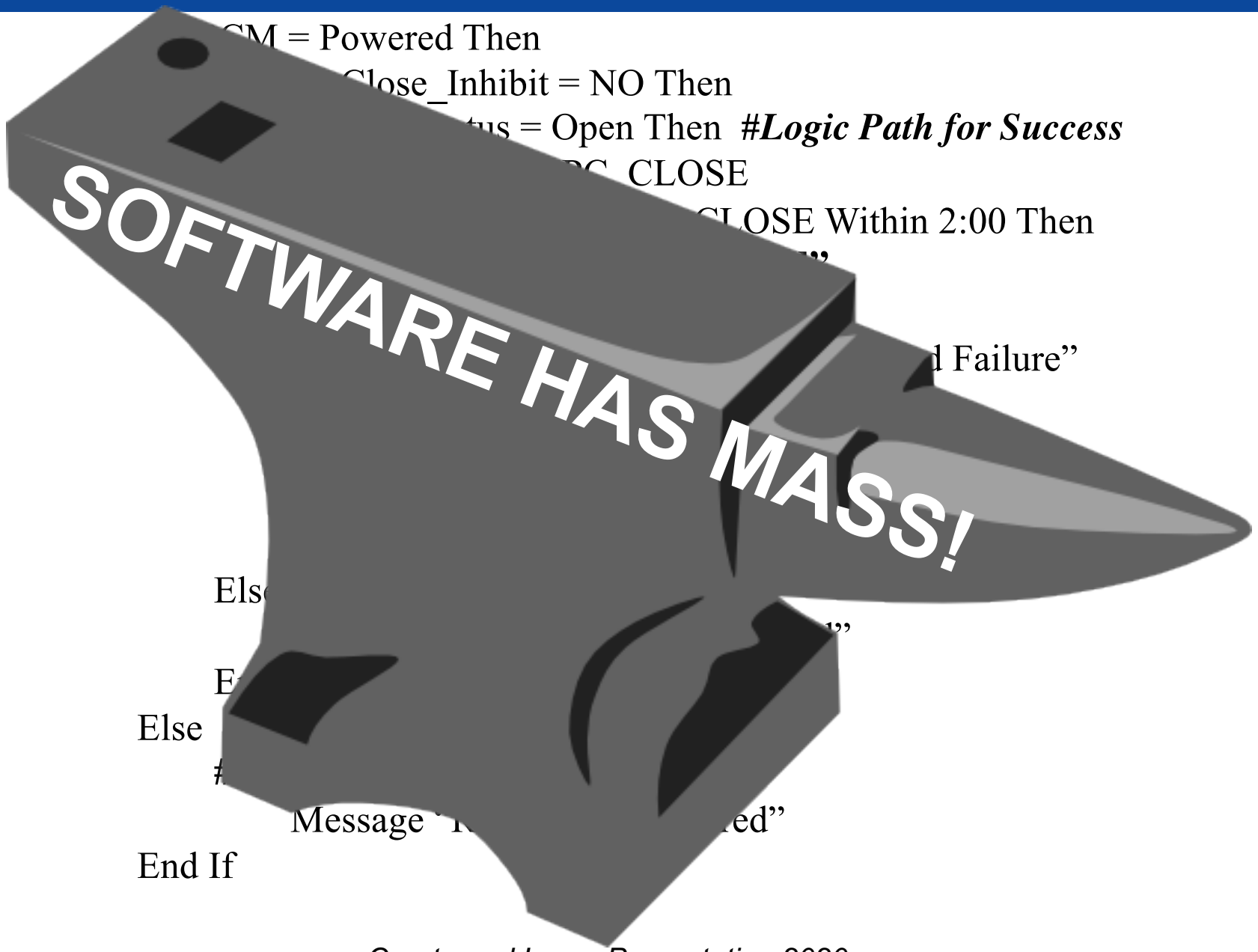


CM = Powered Then
Close_Inhibit = NO Then
tus = Open Then *#Logic Path for Success*
CLOSE
CLOSE Within 2:00 Then
d Failure”
Else
Else
#
Message
ed”
End If

Making it Happen!

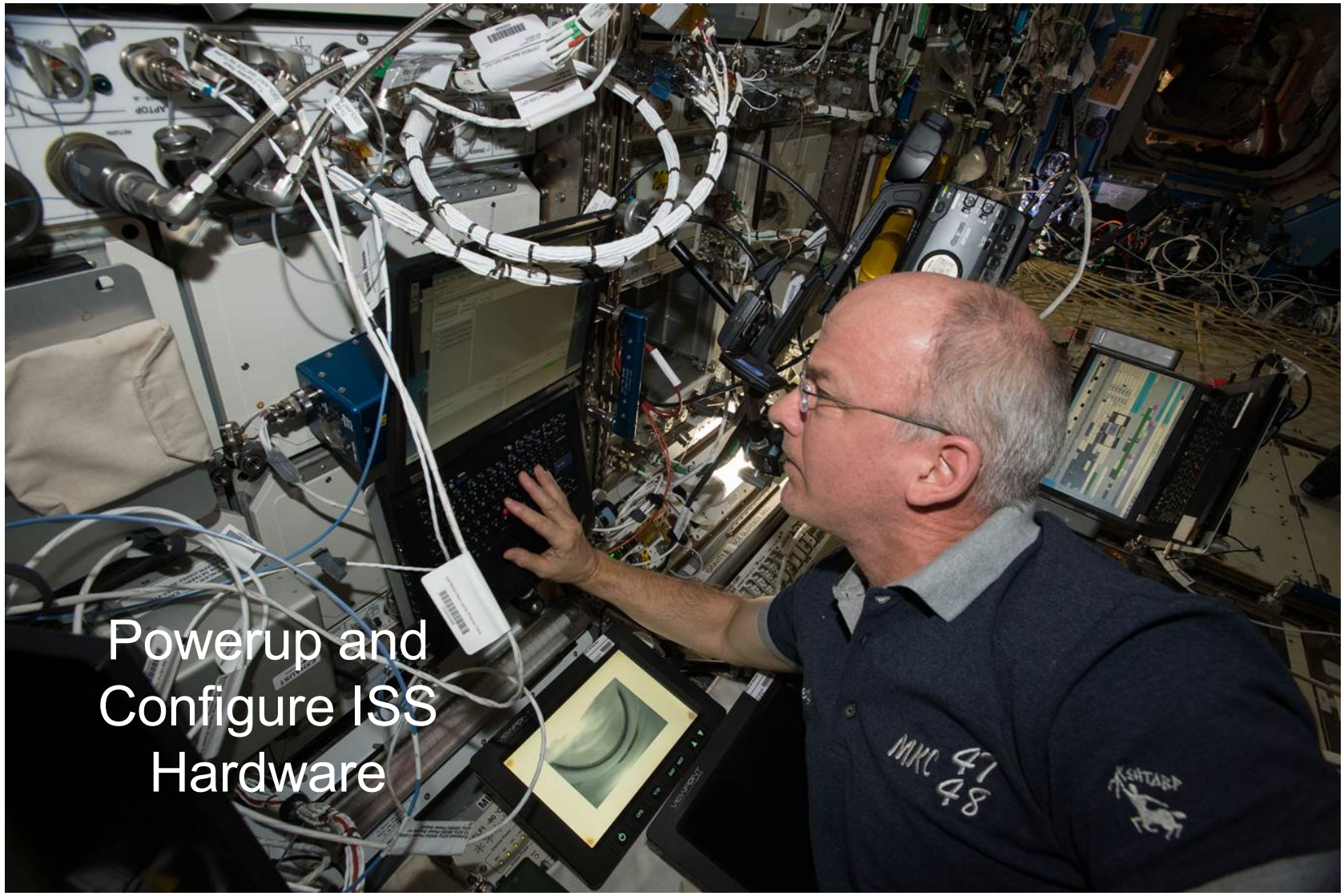
‘Ground’ Testing

Testing Autonomous
Habitat Operations

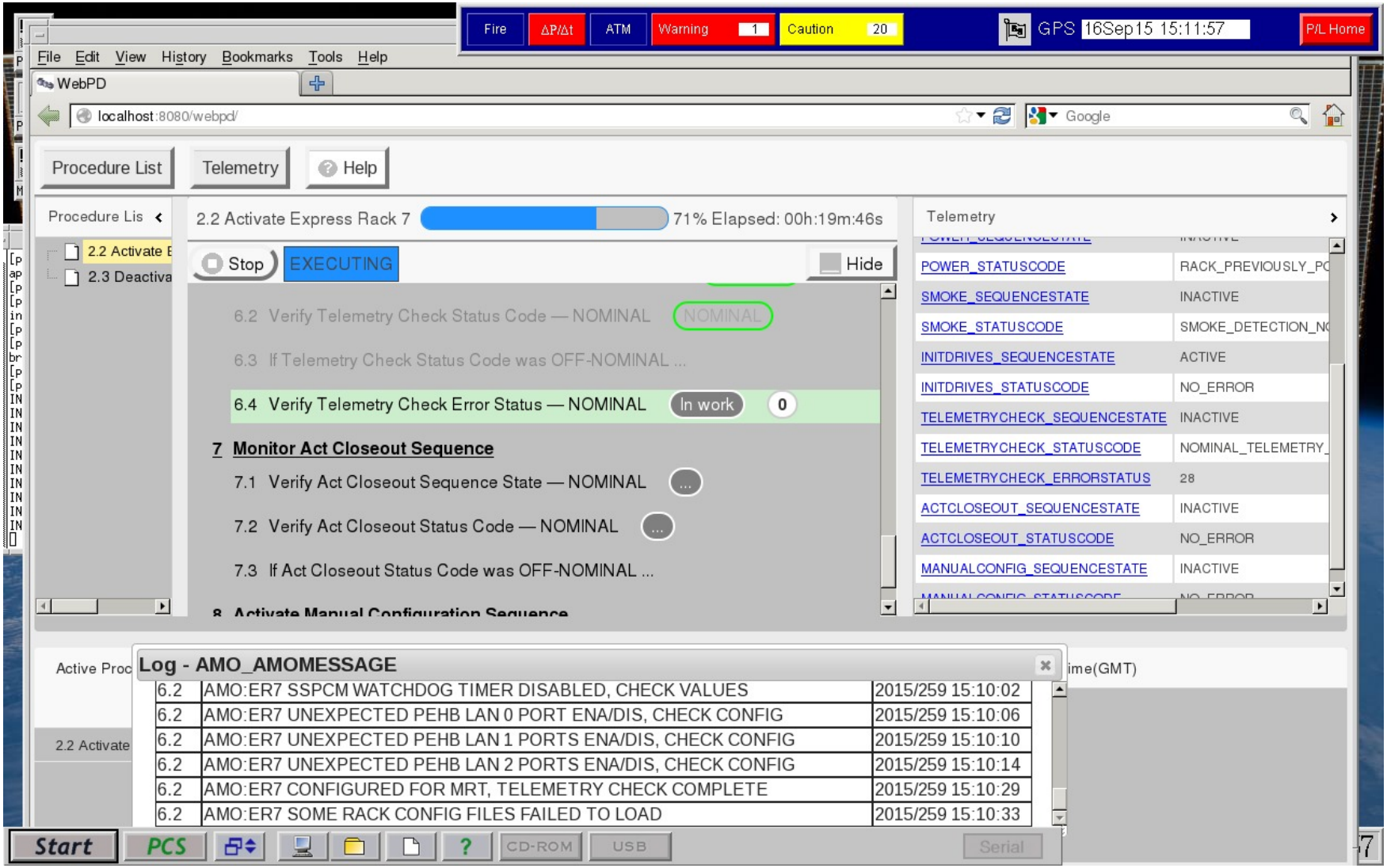
Ground Testing

Ground Testing

Testing onboard the ISS



Testing onboard the ISS



Testing onboard the ISS

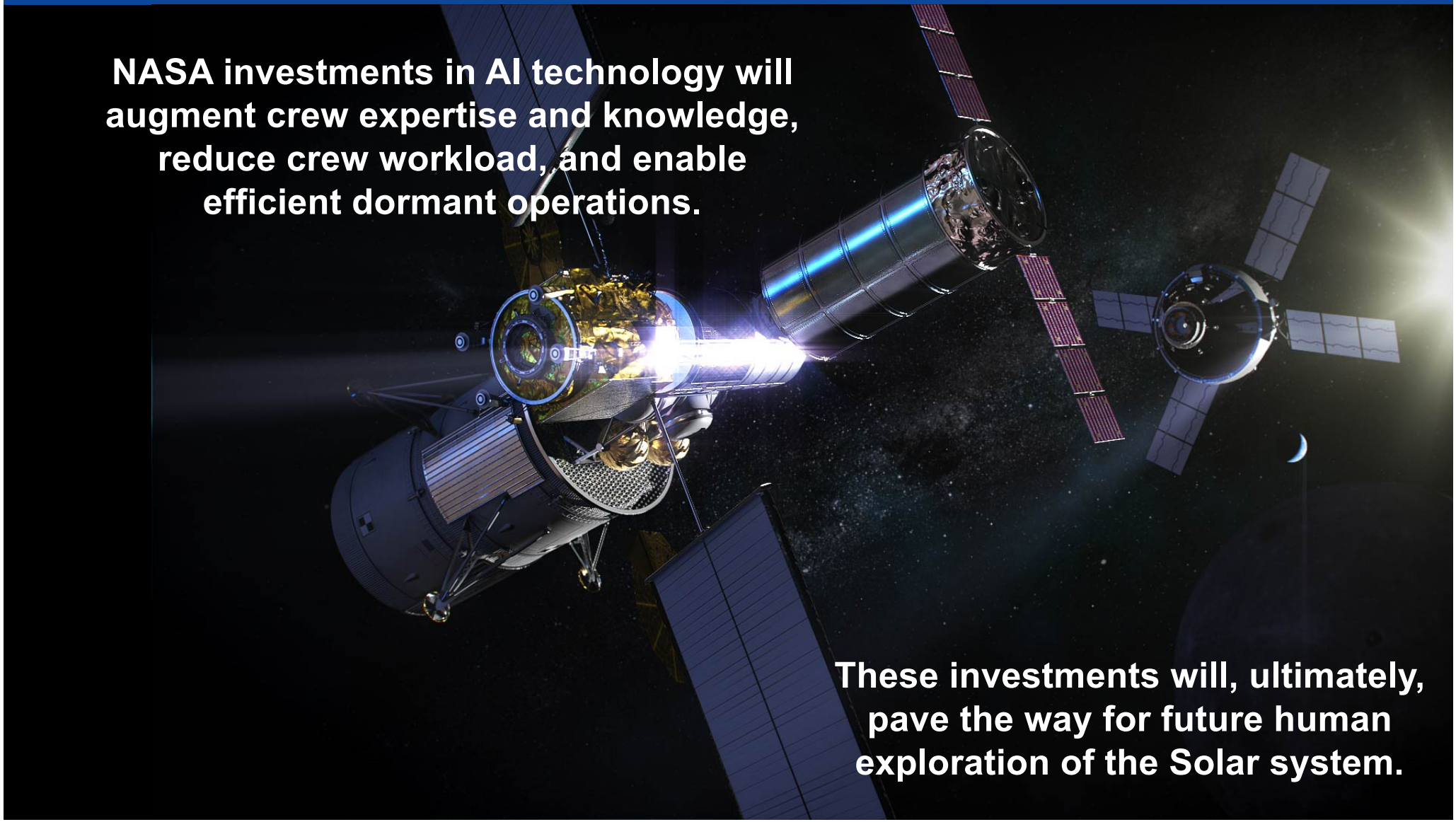
Crew Management of Water Quality Sampling

Testing onboard the ISS

Status	Procedure	Rationale
This Week (GMT 2014/342 - 2014/348)		
Requested	ISTAR Total Organic Carbon Analyzer: TOCA - Waste Water Bag Changeout (Med Ops 6.3.350)	Required every 6 runs and prior to next run
Scheduled	ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)	Required weekly
Next Week (GMT 2014/349 - 2014/355)		
Requested	ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)	Required weekly
Future Week (GMT 2014/356 - 2014/362)		
Recommended	ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis Using TOCA Water Sample Hose (Med Ops 6.3.250)	Required weekly
Recommended	ISTAR Total Organic Carbon Analyzer: TOCA - Water Sample Analysis From TOCA Sample Analysis Bag (Med Ops 6.3.300) (for Hot PWD)	Required monthly (alternating between the hot and ambient ports)

Testing onboard the ISS

Conclusions and Future Work

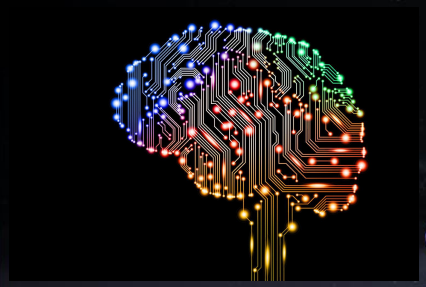


NASA investments in AI technology will augment crew expertise and knowledge, reduce crew workload, and enable efficient dormant operations.

These investments will, ultimately, pave the way for future human exploration of the Solar system.

Conclusions and Future Work

Significant challenges remain!



So Let's Keep Working it!

More Resources!

Learn More About Artemis!

https://www.nasa.gov/stem/artemis.html

Artemis Hour of Code Challenges!

https://www.tynker.com/hour-of-code/nasa-moon-2-mars

NASA K-12 Educator Resources!

https://www.nasa.gov/aeroresearch/resources/k-12